Section 5 d ammonia, contact process and diaphragm cell

1. The modern method of manufacturing ammonia was developed by two German scientists, Haber and Bosch. In 1908 Haber discovered that nitrogen and hydrogen reacted under pressure and in the presence of platinum to give ammonia.

In 1913 Bosch designed a plant to produce 10 000 tonnes of ammonia per year. By 1915 production had risen to 180 000 tonnes per year.
Bosch used iron instead of platinum. To withstand the high pressures in the plant, high carbon steel was used. The carbon in the steel reacted with the hydrogen and made the steel brittle. Bosch lined the reaction vessel with low carbon steel and used an outer casing of high carbon steel to provide the strength. Bosch solved the problem of hydrogen diffusing through the lining of low carbon steel.

(a) (i) Write an equation for the reversible reaction between nitrogen and hydrogen to give ammonia. Include state symbols. [2]
(ii) Why did Haber use platinum? Suggest a reason why Bosch decided to use iron instead. [1]

(b) The table below shows how the percentage of ammonia in the mixture leaving the reaction vessel varies under different conditions

Pressure (atmospheres)	100	200	300	400
% of ammonia at 300 °C	45	65	72	78
% of ammonia at 500 °C	9	18	25	31

(i) On the same grid draw graphs of percentage of ammonia against pressure at 300 °C and 500 °C. [4]

(ii) What is the percentage of ammonia formed at 250 atm and 300 °C? [1]

(iii) Use the graph to estimate the percentage of ammonia formed at 400 °C and 250 atm. [1]

(iv) On the graph, sketch a third line showing the percentage of ammonia you would expect at 400°C. [2]

(v) The advantage of using a low temperature is the large percentage of ammonia formed. What is the disadvantage of using a low temperature? [1]

(vi) Suggest two advantages of using high pressure in the manufacture of ammonia. [2]

2. The equation for the reaction used to manufacture ammonia in the Haber process is

$$3H_2\,(g) \;+\; N_2\,(g) \;\Leftrightarrow\; 2NH_3\,(g) \qquad \Delta H = -92\ kJ\ mol^{-1}$$

A temperature of 450 °C and a pressure of 200 atmosphere are often used.

(a) (i) Where does the nitrogen come from? [1]
(ii) Where does the hydrogen come from? [1]

(b) Complete the table to show what happens to the rate of reaction and yield of ammonia if the conditions are changed as shown. [4]

change	effect on	
	rate of reaction	yield of ammonia
decrease in temperature		
decrease the pressure		
addition of catalyst		

(c) State and explain, using the kinetic theory, the effect on the rate of reaction of increasing the concentration of nitrogen in the Haber process. [3]

(d) Under the conditions used in the Haber process the yield of ammonia is about 15%. What happens to the unreacted nitrogen and hydrogen? [1]

(e) Iron is the catalyst.

(i) Why is the iron on large trays? [1]
(ii) How does this affect the reaction? [1]

(f) What is the function of the condenser in the manufacture of ammonia? [1]

3. (a) For making sulphuric acid, name

(i) the process [1]
(ii) the raw materials [2]
(iii) the catalyst [1]

(b) The reaction between sulphur dioxide and oxygen is *reversible*. What does *reversible* mean? [1]

(c) Is the *breakdown* of sulphur trioxide to sulphur dioxide endothermic or exothermic? [1]

(d) Does *more* sulphur trioxide break down, or *less*, as the temperature rises? Why? [2]